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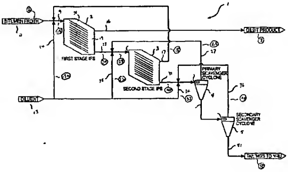
(54) CIRCUIT ET PROCEDE D'EPURATION DES MOUSSES DE BITUME DEGAZEES

(54) CIRCUIT AND PROCESS FOR CLEANING DEAERATED BITUMEN FROTH

(57) Deaerated bitumen froth is cleaned by separating contained bitumen from water and solids contaminants. The froth is countercurrently treated in a three stage circuit comprising primary and secondary inclined plate settlers ("IPS") and a cyclone. Naphtha diluent is added to each of the IPS stages and optionally to the cyclone stage. The combination of increasing diluent/bitumen ratio and separation force is applied to break down emulsion and separate the desired bitumen product from the contaminants.



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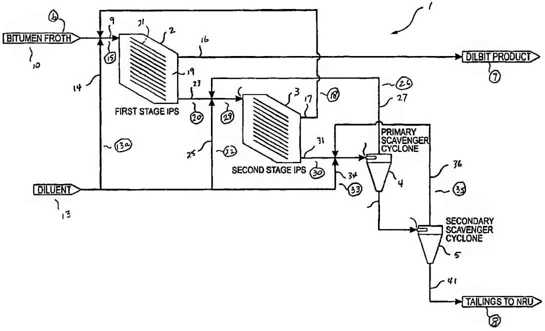

(57) Abrégé/Abstract:
Deaerated bitumen froth is cleaned by separating contained bitumen from water and solids contaminants. The froth is countercurrently treated in a three stage circuit comprising primary and secondary inclined plate settlers ("IPS") and a cyclone. Naphtha diluent is added to each of the IPS stages and optionally to the cyclone stage. The combination of increasing diluent/bitumen ratio and separation force is applied to break down emulsion and separate the desired bitumen product from the contaminants.

"CIRCUIT AND PROCESS FOR CLEANING DEAERATED BITUMEN FROTH"

ABSTRACT OF THE DISCLOSURE

Deaerated bitumen froth is cleaned by separating contained bitumen from water and solids contaminants. The froth is countercurrently treated in a three stage circuit comprising primary and secondary inclined plate settlers ("IPS") and a cyclone. Naphtha diluent is added to each of the IPS stages and optionally to the cyclone stage. The combination of increasing diluent/bitumen ratio and separation force is applied to break down emulsion and separate the desired bitumen product from the contaminants.

"CIRCUIT AND PROCESS FOR CLEANING DEAERATED BITUMEN FROTH"

FIELD OF THE INVENTION

The present invention relates to cleaning deaerated bitumen froth by separating contained water and solids contaminants from the bitumen.

BACKGROUND OF THE INVENTION

For many years now, bitumen has been recovered from the Athabasca oil sands formation in Alberta using a water-based extraction and air flotation technique. In greater detail:

- the as-mined oil sand is mixed with heated water to produce a slurry containing entrained air bubbles; and
- contained bitumen is recovered from the slurry in the form of a froth, by flotation.

The froth contains varying concentrations of water and particulate solids contaminants. The solids comprise coarse sand and fine clay particles. A typical froth might comprise:

bitumen -	60 % by wt.
water -	30 % by wt.
solids -	10 % by wt.

It is necessary to "clean" the froth by removing as much of the water and solids as one can feasibly manage, to prepare it for downstream upgrading.

Before it is cleaned, the froth is substantially deaerated to render it pumpable.

The present invention is directed to providing a circuit and process for cleaning deaerated bitumen froth.

SUMMARY OF THE INVENTION

As previously indicated, the invention is applied to deaerated bitumen froth, such as that produced by an extraction plant associated with an oil sands facility.

The deaerated bitumen froth comprises bitumen, water and coarse and fine solids components, present as a partially emulsified mixture.

The purpose of the invention is to maximize recovery of the bitumen from the froth as a discrete product, while simultaneously removing water and solids.

The difficulty in achieving this objective lies in the fact that, with some of the mixture, it is relatively easy to separate the components, while with the balance it is progressively more difficult to effectively carry out the separation. Otherwise stated, there exists a spectrum of emulsion and a corresponding progressively increasing difficulty in separating the bitumen from the other components.

In a broad sense, the invention presents a countercurrent separation circuit and process wherein:

- the deaerated bitumen froth undergoes two stages of gravity settling, in primary and secondary inclined plate separators ("IPS's"), followed by one or more stages of cyclonic separation;
- coupled with addition of a light hydrocarbon diluent (preferably naphtha) to each of the gravity settling stages and, optionally, to the cyclonic stage(s) as well.

In connection with this process design, the concentration of diluent, expressed as diluent/bitumen ratio ("D/B ratio"), is greater in the secondary gravity settling step than it is in the primary gravity settling step. In other words, the D/B ratio is progressively increased as the water and solids in the emulsion being treated is more tightly bound with the bitumen. In conjunction with increasing the D/B ratio, the separation force applied is increased, as the froth is subjected initially to gravity settling (1g) and then to cyclonic separation (100's of g's).

By having the capability to deliver diluent separately to each of the stages, it is possible to split the overall diluent addition needed for the process between the stages. As a result, more diluent can be allocated to a later stage if the emulsion being treated in the later stage is proving difficult to separate. This provides flexibility to the process.

In one embodiment of the invention, a countercurrent process is provided for recovering bitumen from deaerated bitumen froth containing a mixture of bitumen, water and coarse and fine solids, comprising: providing a froth cleaning process circuit of units comprising primary and secondary inclined plate separators ("IPS's") and a primary cyclone, said units being

connected in sequence for enabling three successive stages of separation; providing a source of light hydrocarbon diluent connected to supply diluent as required to each of the units; feeding froth, diluent and a recycled secondary overflow from the secondary IPS to the primary IPS and controlling the rate of diluent addition to the primary IPS so as to provide a pre-determined primary diluent/bitumen ("D/B") ratio in the primary IPS, and subjecting the resulting mixture to gravity settling in the primary IPS so as to produce an overflow product and a primary underflow; feeding primary underflow, diluent and a recycled cyclone overflow from the primary cyclone to the secondary IPS and controlling the rate of diluent addition to the secondary IPS so as to provide a secondary D/B ratio in the secondary IPS greater than the primary D/B ratio, and subjecting the resulting mixture to gravity settling in the secondary IPS so as to produce secondary overflow and secondary underflow; feeding secondary underflow to the primary cyclone and subjecting it therein to cyclonic separation to produce primary cyclone overflow and primary cyclone underflow; recycling at least part of the secondary IPS overflow to the primary IPS; and recycling at least part of the primary cyclone overflow to the secondary IPS.

In another embodiment, a deaerated bitumen froth cleaning process circuit is provided comprising: a source of deaerated bitumen froth; a source of light hydrocarbon diluent; a primary inclined plate separator ("primary IPS") having an inlet, an outlet for circuit product and an outlet for primary IPS underflow; means, connecting the froth source with the primary IPS inlet, for supplying froth thereto; means, connecting the diluent source with the primary

IPS inlet, for supplying diluent thereto; a secondary inclined plate separator ("secondary IPS") having an inlet, an outlet for secondary IPS overflow and an outlet for secondary IPS underflow; means, connecting the primary IPS underflow outlet with the secondary IPS inlet, for supplying primary IPS underflow thereto; means, connecting the secondary IPS overflow outlet with the primary IPS inlet, for recycling secondary IPS overflow thereto; means, connecting the diluent source with the secondary IPS inlet, for supplying diluent thereto; a primary cyclone having an inlet, an outlet for primary cyclone overflow and an outlet for primary cyclone underflow; means, connecting the secondary IPS underflow outlet with the primary cyclone inlet, for supplying secondary IPS underflow thereto; means, connecting the primary cyclone overflow outlet with the secondary IPS inlet, for supplying primary cyclone overflow thereto; and means, connecting the diluent source with the primary cyclone inlet, for supplying diluent thereto.

DESCRIPTION OF THE DRAWING

Figure 1 is a simplified schematic flow diagram of a circuit in accordance with the invention; and

Figure 2 is a schematic flow diagram of a test circuit used to provide the experimental run data set forth hereinbelow.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The invention is based on a process circuit and a combination of steps applied to a specific feedstock (deaerated bitumen froth) for a specific purpose (cleaning the froth).

There is an underlying preferred scheme with respect to operating the circuit and process, which is now described:

The overall objective of the process is to produce a desired flow rate of clean bitumen for consumption by an upgrader. A naphthenic diluent preferably is used in this process for cleaning bitumen froth, as it provides optimum operating conditions and easy recovery in an upgrader. The design of an upgrader limits the acceptable range of variability in the composition of the naphtha-diluted bitumen (its feed). The composition includes diluent, water and solids in addition to the most important component, bitumen.

The amount of diluent is significant with respect to the amount of bitumen. In fact, to ensure that product specification is met, the mass flow of diluent is ratioed to the mass flow of bitumen. This is called a D/B ratio. This key parameter is used in this froth treatment process to control the overall addition of diluent. That is, a desired flow rate of bitumen (froth) is set and the required diluent (to meet the product D/B ratio) is calculated and subsequently fed. Note that the product D/B ratio is equal to the primary IPS D/B ratio because only the primary IPS produces product.

In the design, the overall D/B ratio is in the range 0.5 – 0.8 and preferably is in the range 0.65 – 0.75. As previously stated, the primary D/B ratio in the primary IPS will closely correspond with the selected overall D/B ratio. The secondary D/B ratio is not set, but will fall in a broad range of 1.0 – 4.0, preferably in the range 1.4 – 2.0. These ranges are selected with the objective of achieving a product containing 0.5 – 2% by wt. water and 0.2 – 1.5% by wt. solids.

It is desirable to directly measure the mass flow of bitumen in the froth. However, due to limitations in instrumentation, it is often necessary to measure the flow of diluted froth (i.e. after the primary diluent flow has been added) and then back-calculate the amount of bitumen. This is easily done with computer control systems in a fraction of a second. Through repeated calculations, the diluent addition is adjusted to zero in on the desired D/B ratio.

The process allows the addition of diluent in various locations (e.g. feed to the primary IPS, feed to the secondary IPS and feed to the primary cyclone). Note that regardless of where the diluent is added it will eventually and substantially come out as product. Therefore, for each volume of diluent that is added to one of the feed locations, a similar volume must be subtracted from another feed location in order to ensure that the product D/B ratio remains essentially constant. Note that the larger the change in diluent flows, the longer it will take for the process to re-establish steady-state.

It is desirable under most conditions to split the diluent addition between the primary and secondary IPS's. While it is technically possible to control the D/B ratio in the secondary IPS (as is done in the primary IPS), it is not practical. The reason is that the feed to the secondary IPS is variable (possibly highly variable if the froth feed composition is changing). Therefore, it is easier to control the split ratio of diluent to the primary versus secondary IPS's. Note that a desired split ratio is first calculated based on expected flow and compositions of the secondary IPS feed. This ratio is then adjusted to zero in on a desired secondary IPS D/B ratio (without causing any significant deviation in the primary IPS product quality).

When operating the primary IPS at the desired froth feed rate and D/B ratio, the underflow is drawn away from the IPS at a specific rate. That rate is a ratio of the underflow to feed rates. Any diluted froth/bitumen that is not drawn off as underflow is pushed over the top and is collected as diluted bitumen product. Note that it is desirable to fine tune the underflow of the primary IPS to draw the emulsion out the bottom for additional treatment rather than allowing it to migrate up and into the product. The emulsion (level and thickness) is monitored using a segmented capacitance probe which shows the percentage of water at various heights in the IPS. Note that the absence of an emulsion layer would be represented by a sharp change in capacitance from a low number representing predominately hydrocarbon to a high number representing predominately water. Conversely, a thick emulsion layer would be represented by a gradual change in capacitance from a low number to a high number.

Having reference now to Figure 1, it shows a process circuit in broad and simplified outline. The invention was tested in a corresponding test circuit 1, which is shown in greater detail in Figure 2. This Figure 2 test circuit will now be described, followed by a Table setting forth the composition analyses, D/B ratios and results of an experimental run. It will be noted that neither Figure 1 or Figure 2 show equipment such as pumps, valves or meters. It is expected that one skilled in the art will insert such equipment as required.

The test circuit 1 comprised a primary IPS 2, a secondary IPS 3, a primary cyclone 4 and an optional secondary cyclone 5 which could be used in or closed out of the circuit. These units were connected in sequence for enabling three or, if desired, four successive stages of separation. The circuit was countercurrent in design. It was adapted to clean deaerated bitumen froth 6 in stages by separating the hydrocarbons (bitumen and diluent) from the water and solids components to separately recover a diluted bitumen product 7, containing small residual amounts of water and solids, and a water and solids tailings 8, containing a small content of residual hydrocarbons.

A source 10 of deaerated bitumen froth 6 was provided. This source was a bitumen extraction plant in an oil sands facility. The froth 6 comprised a partly emulsified mixture of bitumen, water and particulate solids comprising coarse sand and clay fines.

The froth source 10 was connected by line 11 with a primary mixer 12. The mixer 12 was connected by line 9 with the inlet of the primary IPS 2.

A source 13 of hydrotreated naphtha was connected by a line 14 with the primary mixer 12, for supplying primary diluent 13a thereto.

The overflow 18 from the secondary IPS 3 was recycled through line 17 to the primary mixer 12.

The primary mixer 12 was equipped with an impellor and functioned to blend the viscous froth 6 and primary diluent 13a. Recycled secondary IPS overflow 18 was added to produce a resulting mixture 15 fed to the primary IPS 2 through line 9.

The primary IPS 2 was conventional in design. It contained a plate pack 21 of 96 parallel plates of size 3150 x 610 mm spaced apart 38 mm and angled at 55°. The vessel was sized to accommodate a feed rate up to $47 m^3/h$. Overflow was controlled by a weir.

The primary IPS was operated by controlling the D/B ratio of the feed 15, the feed flow and the underflow. The D/B ratio was controlled with the objective of ensuring that the product was within the specification for contaminants. The feed flow was controlled with the objective of ensuring that the IPS loading rate was low enough so that the desired froth cleaning was realizable. And the underflow was controlled with the objective of ensuring that the water, solids and emulsions were drawn away from the product. The overflow was not directly controlled as the liquid level was set by the overflow weir. In addition it was an objective to keep the top level of the emulsion zone below the bottom of the plate pack 21, using the information from a capacitance probe positioned in the IPS.

The primary diluted bitumen product 7 was produced as overflow from the primary IPS 2 through line 16.

The primary IPS underflow 20 was conveyed through line 23 to a secondary mixer 24. Secondary diluent 22 was pumped through line 25 to the secondary mixer 24. And primary cyclone overflow 26 was recycled through line 27 to the secondary mixer 24. The three streams were blended in the mixer and the resulting mixture 28 was fed through line 29 to the inlet of the secondary IPS 3.

The secondary IPS 3 was identical to the primary IPS 2.

The secondary IPS was operated by controlling the primary/secondary diluent split with the objective of ensuring that a D/B range within the desirable range previously given was achieved. The underflow was controlled with the objective of ensuring that the water, solids and emulsions were drawn down. The overflow was not directly controlled as the liquid level was set by the overflow weir. In addition it was an objective to keep the top level of the emulsion zone below the bottom of the plate pack, using the information from a capacitance probe positioned in the IPS.

As previously mentioned, the secondary IPS overflow 18 was recycled to the primary IPS 2.

The secondary IPS underflow 30 was conveyed through line 31 to the inlet of a tertiary mixer 32. Tertiary diluent 33 could be fed through line 34 to the mixer 32. And overflow 35 from the secondary cyclone 5 was recycled through line 36 to the mixer 32. These three streams were blended in the mixer 32 and the resulting mixture 37 fed through line 38 to the inlet of the primary cyclone 4.

The primary cyclone 4 was a Krebs g-Max (trade-mark) cyclone.

The primary cyclone 4 was operated by controlling the feed pressure. Maintaining a target feed pressure maintained g forces, which enhanced emulsion breaking and rejection of unwanted water and solids to the underflow.

As previously indicated, the overflow 26 from the primary cyclone 4 was recycled to the secondary IPS 3.

The underflow 40 from the primary cyclone 4 could be fed directly through line 41 to the inlet of the secondary cyclone 5, which was similar to the primary cyclone 4. The secondary cyclone overflow 35 was recycled to the primary cyclone 4 and its underflow was produced as circuit tailings 8.

The secondary cyclone was also operated by controlling the feed pressure.

An experimental run was conducted in the test circuit 1 and yielded the following data:

Stream #	Stream Description	Flow t/h	Water wt %	Bitumen wt %	Diluent wt %	Mineral wt %	D/B Ratio
6	Froth Feed	13.17	34.21	62.31	0	3.48	0
	Total Diluent	5.22	0.10	0	99.10	0	n/a
13a	Primary Diluent	2.00	0.10	0	99.10	0	n/a
	Diluted Froth Feed	15.17	29.71	54.09	13.18	3.02	0.24
15	Primary IPS Feed	23.32	20.24	48.55	29.07	2.15	0.60
7	Primary IPS Overflow Product	13.42	0.65	60.69	38.34	0.32	0.63
20	Primary IPS Underflow	9.90	46.80	32.09	16.50	4.62	0.51
22	Secondary Diluent	3.20	0.10	0	99.10	0	n/a
28	Secondary IPS Feed	18.29	33.13	26.17	37.08	3.62	1.42
18	Secondary IPS Overflow	8.15	2.63	38.23	58.62	0.52	1.53
30	Secondary IPS Underflow	10.14	57.65	16.47	19.78	6.10	1.20
33	Tertiary Diluent	0.02	0.10	0	99.10	0	n/a
37	Primary Cyclone Feed	15.31	42.61	23.03	29.57	4.78	1.28
26	Primary Cyclone Overflow	5.19	27.46	31.03	37.57	3.94	1.21
40	Primary Cyclone Underflow	10.12	50.38	18.93	25.47	5.22	1.35
	Secondary Cyclone Feed	10.27	51.14	18.64	25.08	5.14	1.35
35	Secondary Cyclone Overflow	5.14	12.94	36.10	48.76	2.19	1.35
8	Secondary Cyclone Underflow	5.14	89.33	1.17	1.41	8.09	1.20

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A countercurrent process for recovering bitumen from deaerated bitumen froth containing a mixture of bitumen, water and coarse and fine solids, comprising:

providing a froth cleaning process circuit comprising primary and secondary inclined plate separators ("IPS's") and a primary cyclone, said units being connected in sequence for enabling three successive stages of separation;

providing a source of light hydrocarbon diluent connected to supply diluent as required to each of the units;

feeding froth, diluent and a recycled secondary overflow from the secondary IPS to the primary IPS and controlling the rate of diluent addition so as to provide a pre-determined primary diluent/bitumen ("D/B") ratio in the primary IPS, and subjecting the resulting mixture to gravity settling in the primary IPS so as to produce an overflow product and a primary underflow;

feeding primary underflow, diluent and a recycled cyclone overflow from the primary cyclone to the secondary IPS and controlling the rate of diluent addition to the secondary IPS so as to provide a secondary D/B ratio in the secondary IPS that is greater than the primary D/B ratio, and subjecting the resulting mixture to gravity settling in the secondary IPS so as to produce secondary overflow and secondary underflow;

feeding secondary underflow to the primary cyclone and subjecting it therein to cyclonic separation to produce primary cyclone overflow and primary cyclone underflow;

recycling at least part of the secondary IPS overflow to the primary IPS; and

recycling at least part of the primary cyclone overflow to the secondary IPS.

2. A deaerated bitumen froth cleaning process circuit comprising:

a source of deaerated bitumen froth;

a source of light hydrocarbon diluent;

a primary inclined plate separator ("primary IPS") having an inlet, an outlet for circuit product and an outlet for primary IPS underflow;

means, connecting the froth source with the primary IPS inlet, for supplying froth thereto;

means, connecting the diluent source with the primary IPS inlet, for supplying diluent thereto;

a secondary inclined plate separator ("secondary IPS") having an inlet, an outlet for secondary IPS overflow and an outlet for secondary IPS underflow;

means, connecting the primary IPS underflow outlet with the secondary IPS inlet, for supplying primary IPS underflow thereto;

means, connecting the secondary IPS overflow outlet with the primary IPS inlet, for recycling secondary IPS overflow thereto;

means, connecting the diluent source with the secondary IPS inlet, for supplying diluent thereto;

a primary cyclone having an inlet, an outlet for primary cyclone overflow and an outlet for primary cyclone underflow;

means, connecting the secondary IPS underflow outlet with the primary cyclone inlet, for supplying secondary IPS underflow thereto;

means, connecting the primary cyclone overflow outlet with the secondary IPS inlet, for supplying primary cyclone overflow thereto; and

means, connecting the diluent source with the primary cyclone inlet, for supplying diluent thereto.

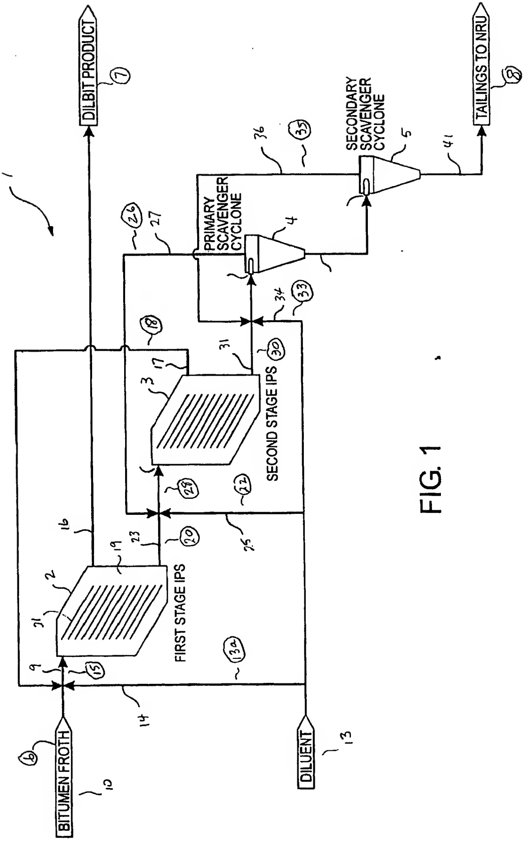
DILBIT PRODUCT
TAILINGS TO NRU
SECONDARY SCAVENGER CYCLONE
PRIMARY SCAVENGER CYCLONE
SECOND STAGE IPS
FIRST STAGE IPS
BITUMEN FROTH
DILUENT

FIG. 1

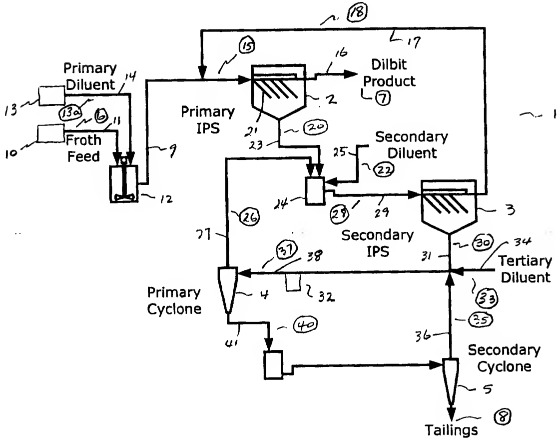

Figure 2: Process Schematic of Test Circuit